the tribe to whom the female belonged. This concludes the the ceremony, and the young man then returns with his wife to his own tribe. He is, however, laid under this peculiar injunction, that he must not see any more his mother-in-law; and the following circumstance in connection with this fact, has been related to me by Mr. Grant, an eye-witness. "A mother-in-law having been descried approaching, a number of leubras formed a circle around the young man, and he himself covered his face with his hands;—this, while it screened the old lady from his sight, served as a warning for her not to approach, as she must never be informed by a third party of the presence of her son-in-law."

The natives, however, of this, as of every other settled part of Australia, are fast disappearing before the rapid encroachments of the white man; in perfect accordance with that universal but mysterious law which governs civilization wherever the white man has planted its flag, sweeping the backward races from the face of the earth.

ART. VI.—*Original Rules and Tables adapted to Cases of Sidelong Ground in the Setting Out and Computation of Railway Earthworks. By* CLEMENT HODGKINSON, C.E., District Surveyor.

HAVING originally investigated and computed the following formulæ and tables for my own use, I venture to submit them to those members of the Philosophical Society who belong to the Engineering Profession.

Before giving my tables for determining the side distances that define, on sidelong ground, the edges of railway cuttings and embankments on both sides of the central line of equidistant stakes, I will briefly state the methods that have been generally followed for determining side distances.

First.—Instrumentally; by means of the well known combination of graduated bars and arcs devised by Sir John Macneil, which, when the sidelong inclination on either side of any stake had been determined by a clinometer or other instrument, admitted of being adjusted so as to show by inspection, on a graduated bar, the required side distance. Sir John Macneil's instrument is not however applicable to those constantly recurring cases in which a railway is partly in cutting and partly in embankment on the same side of a centre stake.

Second.—By successive approximations with the aid of the spirit-level. This method, which has been found well adapted for uneven ground, has been explained in detail in the work of Mr. Frederick Sims, C.E., lately Inspector of Railways for the Hon. East India Company; and has been very frequently employed by other engineers. I however noticed, some years ago, that his rule for determining the side distances, when the cross section showed both cutting and embankment on the same side of any centre stake, was totally wrong, and had occasioned errors of several feet in side distances set off for the South Eastern Railway. As Mr. Simm's work has passed through several editions, and as the erroneous rule alluded to has been since given in another work brought out by the well known publisher, Mr. Weale, I trust this passing allusion to it may not be considered uncalled for.*

Third.—By plotting the cross sections of the ground upon a large scale, and taking the side distances from the diagrams.

Fourth.—By various rules of thumb in vogue among contractors, and not admitting of mathematical demonstration.

Having considered it would be preferable to employ tabulated quantities for determining side distances, in lieu of employing Macneil's instrument, I have derived from the following formulæ the annexed tables of *multipliers,* and I have found that by using these multipliers (which are also applicable to those cases wherein Macneil's instrument fails to be of service), the required side distances can be computed and set off on the ground with more rapidity and certainty than by an instrument whose bars and arcs have to be adjusted at every stake.

Let A B C D (Fig. II.) represent a portion of the cross section of a railway cutting on one side of the centre stake at H: the ground, in this diagram, *converging* from the centre stake towards the plane of base at formation level. Draw

---

* A point being assumed as near the true position of the point D (Fig. I.) on the ground as can be determined by estimation, then the difference of level between that point and the central stake H, minus the height B H, would be the first approximate value of D N, which multiplied by ratios of slope for embankment, would give the first approximate value of C N; which should be added in order to obtain the first approximate value of the side distance, B N, to B C, *the half-width at formation level,* and not to H O, *the computed horizontal half-width for the height* B H, as in Mr. Simm's treatise.

H L, D O, parallel to base A C, and D K perpendicular to H L.

Now let $\frac{b}{2}$ denote half base or B C.
h the height B H at centre stake.
$m : 1$ rate of inclination of slopes.
δ angle of inclination of sidelong ground.
x the required horizontal side distance, or C D

Then D K $= x$ tang δ

$$\mathrm{DK} = \frac{\mathrm{KL}}{m} \frac{\frac{b}{2}\ h + m - x}{m}$$

$$x \text{ tang } \delta = \frac{\frac{b}{2} + h\,m - x}{m}$$

$$x = \frac{b}{2} + h\,m \left(\frac{1}{1 + \text{tang } \delta .\, m}\right)$$

In Fig. III., in which the sidelong inclination *diverges* from the centre stake in reference to the plane of the base, we obtain, in a similar manner,

Side distance or $x = \frac{b}{2} + h\,m \left(\frac{1}{1 - \text{tang } \delta .\, m}\right)$

In Fig. IV. let the profile of the sidelong ground cross the half base, and occasion cutting and embankment on the same side of the centre stake.

Here D K + H L = H L tang δ.

$$\mathrm{D\,K} = \mathrm{H\,L} \text{ tang } \delta - \mathrm{K\,L} = x .\text{ tang } \delta - h$$

$$\mathrm{D\,K} = \frac{\mathrm{C\,K}}{m} = \frac{x - b}{m}$$

$$x .\text{ tang } \delta - h = \frac{x - b}{m}$$

$$x = b - h\,m \left(\frac{1}{1 - \text{tang } \delta .\, m}\right)$$

In Table No. I. I have given values of $\frac{1}{1 - \text{tang } \delta .\, m}$ for the more ordinary slopes, and in Table No. II. similar values of $\frac{1}{1 + \text{tang } \delta .\, m}$

TABLE—No. I.

$$\frac{1}{1 - \text{tang}\ \delta .\ m}$$

INCLINATION.	SLOPES.			
	1 to 1	1½ to 1	2 to 1	2½ to 1
° ′				
0 — 0	1·000	1·000	1·000	1·000
0 10	1·003	1·004	1.006	1·009
20	1·006	1·009	1·011	1·014
30	1·009	1·013	1·017	1·021
40	1·012	1·017	1·023	1·028
50	1·015	1·022	1·029	1·036
1 — 0	1·018	1·027	1·036	1·044
10	1·021	1·031	1·042	1·052
20	1·024	1·035	1·048	1·060
30	1·027	1·039	1·054	1·068
40	1·030	1·044	1·061	1·077
50	1·033	1·049	1·068	1·086
2 — 0	1·036	1·054	1·075	1·096
10	1·039	1·059	1·081	1·105
20	1·042	1·064	1·088	1·114
30	1·045	1·069	1·095	1·123
40	1·048	1·074	1·102	1·132
50	1·051	1·079	1·109	1·141
3 — 0	1·055	1·085	1·117	1·151
10	1·058	1·090	1·124	1·161
20	1·061	1·095	1·131	1·171
30	1·064	1·100	1·139	1·181
40	1·068	1·105	1·147	1·191
50	1·071	1·111	1·155	1·201
4 — 0	1·075	1·117	1·163	1·212
10	1·078	1·122	1·171	1·223
20	1·081	1·127	1·179	1·234
30	1·084	1·133	1·187	1·245
40	1·088	1·139	1·195	1·256
50	1·092	1·145	1·203	1·268
5 — 0	1·096	1·151	1·212	1·280
10	1·100	1·157	1·221	1·292
20	1·103	1·163	1·230	1·304
30	1·106	1·169	1·239	1·317
40	1·110	1·175	1·248	1·330
50	1·114	1·181	1·257	1·343

TABLE—NO. I.—*continued.*

INCLINATION.	SLOPES.			
	1 to 1	1½ to 1	2 to 1	2½ to 1
° ′				
6 — 0	1·118	1·187	1·266	1·356
10	1·121	1·193	1·276	1·370
20	1·125	1·199	1·285	1·384
30	1·129	1·205	1·295	1·398
40	1·132	1·212	1·305	1·413
50	1·136	1·219	1·315	1·428
7 — 0	1·140	1·226	1·325	1·443
10	1·143	1·232	1·335	1·458
20	1·147	1·239	1·345	1·474
30	1·151	1·246	1·356	1·491
40	1·155	1·253	1·367	1·508
50	1·159	1·260	1·378	1·525
8 — 0	1·163	1·267	1·390	1·542
10	1·167	1·274	1·402	1·550
20	1·171	1·281	1·414	1·578
30	1·175	1·288	1·426	1·597
40	1·179	1·296	1·438	1·616
50	1·183	1·304	1·451	1·635
9 — 0	1·188	1·312	1·464	1·655
10	1·192	1·319	1·477	1·675
20	1·196	1·327	1·490	1·696
30	1·200	1·335	1·503	1·718
40	1·204	1·343	1·517	1·741
50	1·209	1·351	1·531	1·764
10 — 0	1·214	1·359	1·545	1·788
10	1·218	1·367	1·559	1·813
20	1·222	1·376	1·574	1·839
30	1·226	1·385	1·589	1·865
40	1·231	1·394	1·604	1·892
50	1·236	1.403	1·620	1·919
11 — 0	1·241	1·412	1·636	1·947
10	1·245	1·421	1·652	1·976
20	1·250	1·430	1·669	2·006
30	1·255	1·439	1·686	2·037
40	1·260	1·448	1·704	2·069
50	1·265	1·458	1·722	2·102
12 — 0	1·270	1·468	1·740	2·136
10	1·275	1·478	1·759	2·171
20	1·280	1·488	1·779	2·207
30	1·285	1·498	1·799	2·244
40	1·290	1·508	1·819	2·283
50	1·295	1·519	1·840	2·323

TABLE—NO. I.—*continued.*

INCLINATION.	SLOPES.			
	1 to 1	1½ to 1	2 to 1	2½ to 1
° ′				
13 — 0	1·300	1·530	1·860	2·365
10	1·305	1·541	1·881	2·408
20	1·310	1·552	1·902	2·453
30	1·315	1·563	1·924	2·500
40	1·320	1·574	1·947	2·549
50	1·326	1·575	1·971	2·601
14 — 0	1·332	1·597	1·997	2·655
10	1·337	1·609	2·022	2·711
20	1·342	1·621	2·048	2·769
30	1·348	1·633	2·074	2·830
40	1·354	1·645	2·101	2·893
50	1·360	1·658	2·128	2·960
15 — 0	1·366	1·671	2·156	3·030
10	1·372	1·684	2·185	3·104
20	1·378	1·698	2·215	3·182
30	1·384	1·712	2·246	3·264
40	1·390	1·726	2·278	3·350
50	1·396	1·740	2·310	3·440
16 — 0	1·400	1·754	2·344	3·534
10	1·407	1·769	2·380	3·633
20	1·414	1·784	2·417	3·740
30	1·420	1·799	2·455	3·855
40	1·426	1·814	2·494	3·978
50	1·433	1·830	2·534	4·109
17 — 0	1·440	1·846	2·575	4·250
10	1·447	1·863	2·617	4·402
20	1·454	1·880	2·661	4·565
30	1·461	1·897	2·707	4·739
40	1·468	1·914	2·755	4·924
50	1·475	1·932	2·805	5·120
18 — 0	1·482	1·950	2·856	5·328

TABLE—No. II.

$$\frac{1}{1 + \text{tang } \delta .\, m}$$

SIDELONG INCLINATION.	SLOPE 1 to 1	SLOPE 1½ to 1	SLOPE 2 to 1	SLOPE 2½ to 1
° ′				
0 — 0	1·000	1·000	1·000	1·000
10	·997	·996	·994	·993
20	·994	·991	·988	·986
30	991	·987	·982	·980
40	·988	·982	·977	·973
50	·985	·978	·971	·966
1 — 0	·982	·974	·966	·959
20	·977	·967	·956	·946
40	·972	·958	·945	·933
2 — 0	·966	·951	·935	·922
20	·961	·943	·924	·909
40	·956	·936	·915	·897
3 — 0	·950	·928	·905	·885
20	·945	·920	·896	·873
40	·940	·912	·887	·861
4 — 0	·935	·905	·878	·850
20	·930	·898	·869	·839
40	·925	·891	·860	·829
5 — 0	·920	·884	·851	·819
20	·915	·877	·842	·809
40	·910	870	·834	·800
6 — 0	·905	·863	·826	·791
20	·900	·857	·818	·782
40	·895	·851	·810	·773
7 — 0	·890	·846	·802	·764
20	·885	·839	·791	·756
40	·881	·833	·787	·748
8 — 0	·876	·826	·781	·740
20	·871	·820	·773	·732
40	·866	·813	·765	·724
9 — 0	·862	·808	·759	·717
20	·858	·802	·752	·709
40	·854	·796	·745	·701
10 — 0	·850	·790	·739	·694
20	·845	·784	·733	·687
40	·841	·778	·726	·680

TABLE—NO. II.—*continued.*

SIDELONG INCLINATION.	SLOPE 1 to 1	SLOPE 1½ to 1	SLOPE 2 to 1	SLOPE 2½ to 1
° ′				
11 — 0	·836	·772	·719	·673
20	·832	·767	·713	·666
40	·828	·762	·707	·659
12 — 0	·824	·758	·701	·653
20	·820	·753	·695	·646
40	·816	·748	·689	·640
13 — 0	·812	·743	·683	·634
20	·808	·738	·677	·628
40	·804	·733	·672	·622
14 — 0	·800	·728	·667	·616
20	·796	·723	·661	·610
40	·792	·718	·656	·604
15 — 0	·788	·713	·650	·598
20	·784	·708	·645	·592
40	·780	·703	·640	·587
16 — 0	·777	·699	·635	·582
20	·773	·694	·630	·577
40	·769	·690	·625	·572
17 — 0	·765	·685	·620	·567
20	·761	·680	·615	·562
40	·757	·676	·610	·557
18 — 0	·754	·672	·606	·551

EXAMPLE OF APPLICATION OF TABLES.

Nature of earthwork.	No. of stake.	Base.	Slopes.	Heights.	Horizontal ½ widths corresponding to heights.	Sidelong Inclination.		Tabular multipliers.		Required side distances.	
						Left.	Right.	Left.	Right.	Left.	Right.
Cutting	46	30	1to1	10·2	25·2	Dep. 6° 30′	El. 6° 0′	·903	1·118	22·8	28·2
do	47	do	do	7	21	6 20	4 40	·900	1·088	18·9	22·8
do	48	do	do	3·4	18·4	6 0	6 0	·905	1·118	16·7	20·6
do	49	do	do	1·2	16·2	5 40	5 30	1·175 ·910 }	1·106	15·5	17·9
Embank.	50	do	1½-1	3	19·5	5 20	5 20	1·163	·877	22·7	17·1

The tabular multipliers corresponding to angles of *elevation* for *cuttings,* and *depression* for *embankments,* are taken from Table No. I.; and those corresponding to angles of *depression* for *cuttings,* and *elevation* for *embankments,* are taken from Table No. II. Whenever the product of the horizontal half width (in column 6), by a tabular number, is *less* than the half base, it is an indication that there will be both cutting and embankment on the same side of the centre stake. This is the case on the left side of stake No. 49 of the given example; and the required side distance, in this instance, is obtained by deducting from the half base, or 15, the product of the height 1·2 by the slope of embankment 1½, and then multiplying this difference by the corresponding tabular number 1·175, taken from Table II., in accordance with the Formula No. III.

Formula for occasional use in computing the volume of a portion of a Cutting or Embankment between two consecutive centre pegs, when the sidelong inclination differs considerably at each peg.

I VENTURE to submit the following investigation of the volume of earthwork having rapidly changing profiles; as any rule that would tend to the attainment of greater accuracy in the computation of cubic contents in such cases, might be sometimes applicable in this colony, where the great cost of earthworks renders precision in the estimated contents thereof a matter of very great importance.

The French have made long and complicated investigations in connexion with the subject of *deblais* and *remblais,* but their formulæ are too abstruse for any practical application, and their tables for facilitating ordinary computation of earthwork, are less convenient than Bidder's improved tables and some others in use by British engineers.

I am indebted to the French for the hypothesis of the mode in which the surface of the ground may be conceived to be generated in the following investigation; but the investigation itself, and comparatively simple formula obtained, are my own.

Let A B C D E F G H (Fig. V.) represent a portion of railway cutting between consecutive stakes, and let the sidelong angle of inclination H G H′ be not equal to the sidelong angle of inclination D C D′ at the other end of this earthwork. In the first place it is evident that the surface D C G H is not a plane surface, but a contorted surface, and it may be conceived to

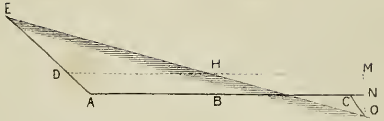


Fig.1.

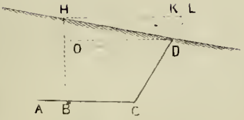


Fig 2

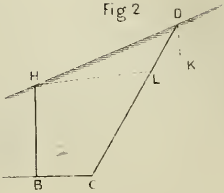


Fig 3.

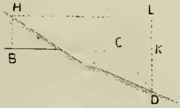


Fig 4

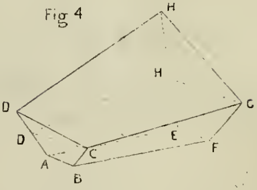


Fig 5

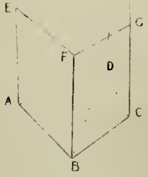
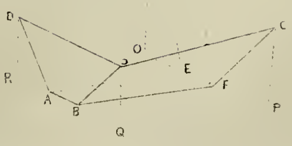


Fig 6.



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